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Improving performance of primary air fansin thermal power plants through energy conservation techniques

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Primary Air Fans are the essential auxiliary equipment to provide the primary air to lift the pulverized coal from mills to carry to burners and also to provide partial air for combustion. This paper describes various techno-economical energy conservation measures for reducing the carbon emission by improving the performance of Primary Air fans in coal fired thermal power plants based on the energy conservation/audit study conducted in 28 numbers of 210 MW power plants in India. The best operating points for pressure gain, flow, pressure drop across hydrodynamic resistive elements, equipment efficiency, power input and specific energy consumption are simulated by using MATLAB and presented in this paper with case study to validate the results. Optimizing the pressure at PA fan discharge, control of excess air, pressure drop across APH and mills and maintaining the optimum primary air pressure at mills thereby to maintain appropriate coal-air pressure at burners will help in reduction of auxiliary power of PA fans. The implementation of energy conservation measures in a typical 210 MW coal fired thermal power plant reduce the overall auxiliary power of PA fans by 0.26 % of gross energy generation and also reduce the carbon emission by 4,056 t/year.

Keywords: *Energy efficiency, carbon emission, primary air fans, excess air, auxiliary power,* fan efficiency

1.0 INTRODUCTION

The Indian power sector mainly depends on the power generation by coal/lignite that forms about 58 % of 223.334 GW as on 31st march 2013 (i.e., end of 1st year of 12th five year plan [1]). The estimated CO_2 emission is about 13 million t/h. Due to acute shortage of power and higher gap between power supply and demand i.e., 8.98 % of peak demand shortage, Indian power sector is planning to add power generation by coal of about 62,695 MW in 12th five year plan (2012-17) which will emit an additional CO_2 of about 3.5 million t/h [2]. The main drawbacks of power generation through coal based technology are CO_2 emission, ash disposal, global warming, water requirement, etc. The adoption of new energy efficient technologies like ultra-super critical technology for power generation provides some relief for pollution control. But due to available Indian coal is of poor quality and depend on imported coal from other countries like Indonasia, South Africa, Austrailia, etc. The various methods are being used for reducing the CO_2 emission in thermal power plants. Among all the available techniques of reduction of CO_2 emission is implementation of energy conservation measures is the economical viable solution.

The estimated auxiliary power used for running the coal fired thermal power plants in India is about 11,340 MW that forms average of about

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8.4 % of coal based power plants & 4.9 % of total installed capacity [3]. The power boilers used for electricity generation generally work on the principle of balanced draft system i.e., Forced Draft (FD) for pushing air into the furnace, Primary Air (PA) fans for pumping the pulverized coal along with air into the furnace, Induced Draft (ID) fans to suck the flue gas from the furnace and throw out the flue gas to atmosphere through chimney. Both air fans provide positive pressure to furnace whereas ID fans provide slightly negative pressure compared to positive pressure supplied by air fans to maintain the furnace pressure always on negative side in the range of -30 Pa to -80 Pa for safety reasons [4]. In a coal fired thermal power plant, for combustion, two types of air circuits are used i.e., primary air to lift the pulverized coal from mills to burners and secondary air for atomizing the coal at burners [5], [6].

The primary air is heated in two numbers of rotary re-generative type tri-sectored Air Pre-heaters (APH). APH consists of three sectors, flue gas is passed in one sector, primary air is passed in second sector and third sector is for primary air. The flue gas pressure will be negative pressure (draft) whereas primary air pressure will be high in the range of 7.85 to 8.83 kPa and secondary air pressure will be low in the range of 1.95 to 2.95 kPa. PA fans have to provide the necessary air pressure to overcome the power loss in APH, air ducts and Mills (Figure 1).

In a typical 210 MW power plant, there are two numbers of PA fans of 1250 or 1300 kW; both fans will be working continuously. The average specific auxiliary power (SAP) used by PA fans is 0.93 % of gross power generation and 10.6 % of total auxiliary power at maximum continuous rating (MCR). The SAP is high compared to design value of 0.49 % of gross power generation at MCR condition. The auxiliary power used by PA fans varies widely due to use of different grade coals and different operating conditions [6]. The primary air flow is controlled by either inlet guide vane (IGV) or damper control. But in few power plants, hydraulic scoop coupling is also installed for PA fans.

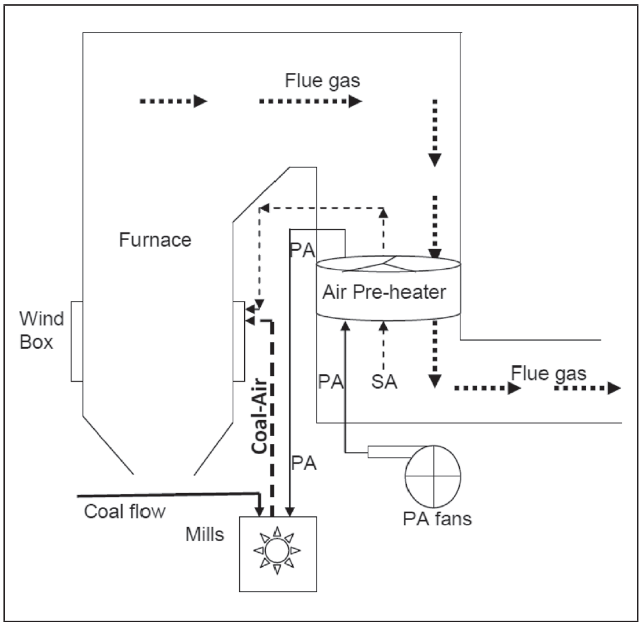

FIG. 1 SCHEMATIC OF PRIMARY AIR CIRUIT

2.0 PERFORMANCE EVALUATION OF PA FANS

The performance test is conducted on PA fans as a part of energy audit study in 28 units of 210 MW units with similar design of PA fans in India to evaluate the energy losses in PA fans and to reduce these losses. The environmental burden of CO_2 can be reduced by improving the energy efficiency of PA fans through implementation of energy conservation measures and operational optimization. During this performance test, the plant load is maintained nearly constant (load variation < 3 %) for a period of 120 minutes continuously; coal from the same source is used; no change-over of auxiliary equipment; no intermittent bottom ashing; and no soot-blowing operation during the test. During performance test, the power supply parameters are recorded by power analyzers; process parameters like pressure is recorded by digital pressure transducers, temperature by digital temperature recorders, air flow by pitot tubes and digital micro-manometers. Oxygen content in flue gas at before APH and after APH is measured by using combustion analyzer.

3.0 MATHEMATICAL MODELING AND SIMULATION STUDIES

The input power to PA fan-motor depends on the efficiency of fans, motors, pressure gain (net head i.e., dynamic head & velocity head) across fan and flow.

$$P_{in}\alpha\frac{\Delta PR \times \overset{o}{m}}{\eta_m \times \eta_f} \quad ....(1)$$

Where P_{in} is the input power, ΔPR is the pressure gain across fan, $\overset{o}{m}$ is the primary air flow, η_m is the motor efficiency and η_f is the fan efficiency.

PA fans have to overcome the pressure drop offered by hydrodynamic resistive element like APH, air ducts and mills.

All these variables are directly dependent on the plant load factor (PLF) and are plotted with variation in plant load factor (array). The Pearson product moment correlation method is used for finding the correlation coefficient (R^2) between x-axis array (i.e., PLF independent variable) and y-axis array (i.e., P_{in}, ΔPR, ΔP_{APH}, and $\overset{o}{m}$ η_O as dependent variables)

$$r=\frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}} \quad ....(2)$$

Where x is the mean of array 1 of PLF, y is the mean of array 2 of dependent variables i.e., ΔPR, ΔP_{APH}, $\overset{o}{m}$, η_O and P_{in}; and $\bar{x}$ are $\bar{y}$ variables from array 1 & array 2 respectively.

In order to simulate the variation of power input to PA fans with plant load factors, all the above mentioned variables are considered for simulation. The simulation of variation of auxiliary power with plant load is carried out with respect to variation in pressure gain, pressure drop across APH, primary airflow and overall efficiency. The Artificial Neural Network (ANN) feed forward technique is adopted to simulate the variation of power input. In this technique, three layer model is adopted i.e., input layer, hidden layer and output layer [7].

ANNs are computational models which simulate the function of biological networks that composed of neurons [8]. The unique concept of ANN is the multi layered feed forward neural networks. Figure 2 is the ANN architecture.

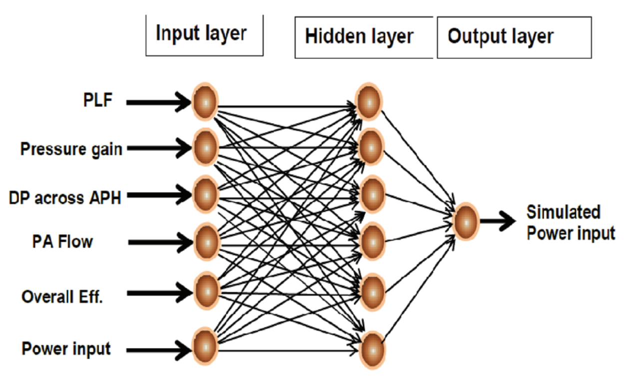

FIG. 2 ANN ARCHITECTURE FOR PA FANS

In this case three layer concept is adopted. A node in one layer is connected to all nodes in the next layer i.e., feed forward architecture. The input layer takes all the input parameter, the information is transmitted to hidden layer where they will be processed and output is computed in output layer [9]. In this study, the input layers are chosen as plant load factor, pressure gain, primary airflow, overall efficiency, measured electrical power input and pressure drop across APH. Back propagation training algorithm which is a gradient descent technique to minimize the sum of square errors is used. The output layer is the simulated power input to PA fan motors.

$$E=\sum_{i=1}^{N}\sum_{j=1}^{Q}\left(AP_{in}-AP_{PA}\right)^2 \quad ....(3)$$

Where AP in is the simulated power input (%), i is input data set value from 1 to N, j is the output data set value from 1 to Q. The simulation will try to minimize the error near to zero.

4.0 RESULTS AND DISCUSSIONS

4.1 Pressure variation

As the plant load on the unit increases, the discharge pressure at fan increases to provide the necessary primary air pressure at Mills inlet (Figure 3). PA fans have to provide the PA pressure at Mills inlet to about 6.6 kPa and overcome the pressure drop across APH of about 0.42 kPa and average differential pressure of about 3.4 kPa in Mills at MCR condition. The deviation in pressure gain with variation in plant load factor from 70 % to 100 % (MCR) is computed by using the MATLAB software.

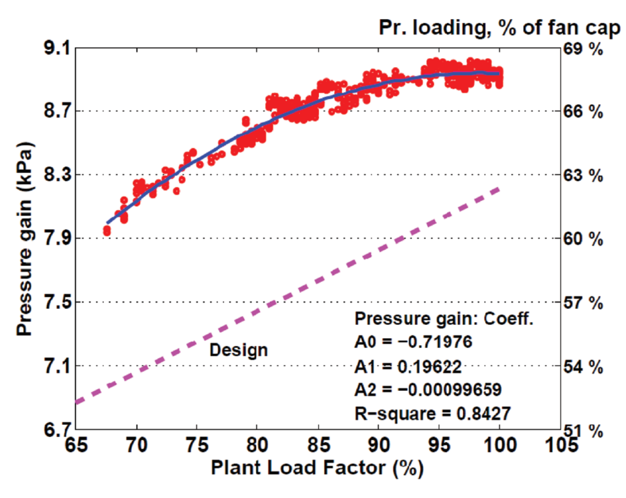

FIG. 3 PRESSURE GAIN ACROSS PA FANS

The correlation coefficient for the measured pressure gain with PLF is 0.8427 and the noise level in data is slightly more. At MCR condition, the average measured pressure gain is 8.94kPa and is higher than the design value of 8.21 kPa at MCR condition. The pressure gain at full load capacity of PA fan (max. efficiency point) is 11.87 kPa. The margin provided for operation of PA fans at MCR condition is about 31 % but the actual average measured operating point of PA fans is about 25 % of full load capacity of fans. This operation of PA fans at non optimal operating point cause drastic reduction in efficiency of fans that increase the power loss. The power loss difference between operating point with design pressure gain at MCR condition is 0.007 % of gross generation and the power loss compared at actual measured operating point at MCR condition is 0.02 %. The higher pressure gain at PA fans is mainly because of fear of use of poor coal quality. Since the optimal PA pressure at mill inlet can be maintained in the range of 6.0 to 6.4 kPa, the PA fan discharge pressure can be maintained to about 7.0 to 7.2 kPa. The measured average pressure gain at 70 % PLF is 8.13 kPa and is higher than the design value of 7.06 kPa. The deviation in pressure gain (%) measured at different plant loading is computed with respect to operating the plant load at MCR condition and the deviation is computed as:

$$\partial P_r = \left(1 - \frac{PR_T}{PR_{MCR}}\right) \times 100 \quad ....(4)$$

Where PR_{MCR} is the pressure gain at MCR condition (kPa) and PR_T is the pressure gain at tested plant load (kPa). The deviation in pressure gain for operating the plant at 70 % of MCR is 9.1 % (Figure 4).

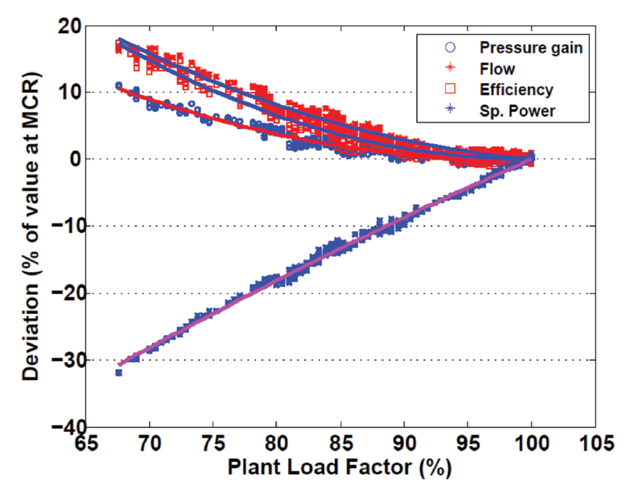

FIG. 4 DEVIATION IN PARMATERS WITH PLF

The correlation coefficient for the variation of pressure drop across APH is 0.8427 and the noise level in data is slightly high. The average measured PA pressure drop across APH is 1.02 kPa and is higher compared to design value of 0.42 kPa at MCR condition. The higher pressure drop may be due to blocking of air baskets. The measured value at 70 % PLF is 0.90 kPa which is higher compared to design value of 0.22 kPa.

The power loss (kW) due to PA pressure drop across APH is computed as:

$$L_{APH} = \Delta P_{APHi} \times \overset{o}{m} \quad ....(5)$$

Where ΔP_{APH} is PA pressure drop (kPa) across APH and is the PA flow at PA fan discharge (m^3/s).

The correlation coefficient for the variation of power loss in APH is 0.9188 and the noise level in data is slightly high. The average computed power loss across APH at MCR condition is 82.48 kW and is higher compared to design value of 31.22 kW. The APH power loss forms about 4.21 % of total power input to PA fans (Figure 5). The measured power loss at 70 % PLF is 60.99 kW which is higher compared to design value of 12.44 kW.

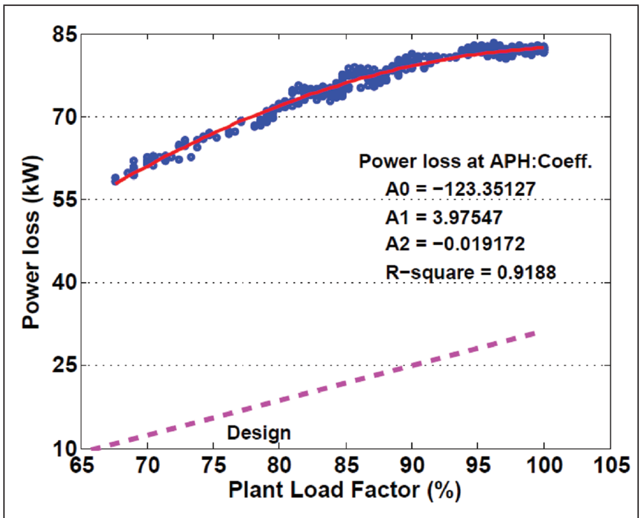

FIG. 5 VARIATION OF POWER LOSS IN APH WITH PLF

4.2 Flow Variation

The correlation coefficient for the measured PA flow with PLF is 0.9351 (Figure 6) and the noise level in data is less. At MCR condition the average measured PA flow is 80.66 m^3/s and is higher than the design value of 73.99 m^3/s at MCR condition due to use of poor coal quality. The calorific value of coal measured during the performance test was varying between 2,800 kcal/kg to 3,600 kcal/kg and is lower than the average design value of 4,000 kcal/kg.

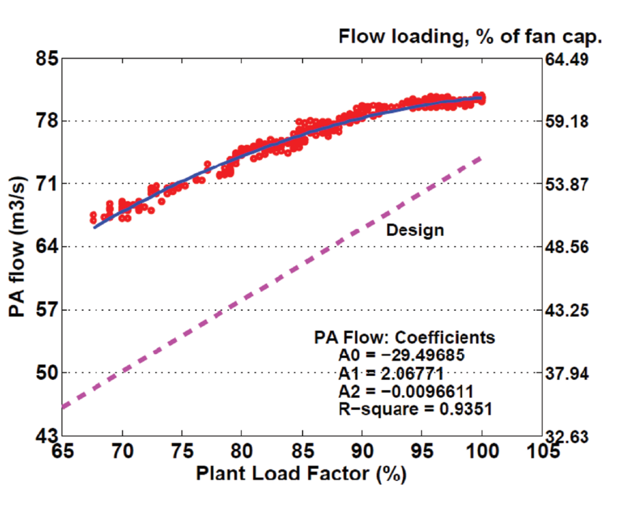

FIG. 6 VARIATION OF PA FLOW WITH PLF

The ash content of coal during the performance test was varying between 42.8 % to 58.9 % and is higher compared to average design value of 32 %. The lower calorific value and higher ash content of coal require more primary air to lift the coal from mills to burners for combustion. The PA flow at full load capacity of PA fans (fan max. efficiency point) is 148 m^3/s (74 m^3/s per fan). The margin provided for operation of PA fans at MCR condition is about 50 % but the actual average measured operating point of PA fans is about 54.5 % of load capacity of fans. The measured average PA flow at 70 % PLF is 67.90 m^3/s and is higher than the design value of 50.05 m^3/s. The deviation in PA flow (%) measured at different plant loading is computed with respect to operating the plant load at MCR condition and the deviation (%) is computed as:

$$\partial \overset{o}{m} = \left(1 - \frac{\overset{o}{m}_T}{\overset{o}{m}_{MCR}}\right) \times 100 \quad ....(6)$$

Where $\overset{o}{m}_{MCR}$ is the PA flow at MCR condition (m^3/s) and $\overset{o}{m}_T$ is the PA flow (m^3/s) at tested plant load. The deviation in SA flow for operating the plant at 70 % of MCR is 15.8 % and is high compared to pressure gain.

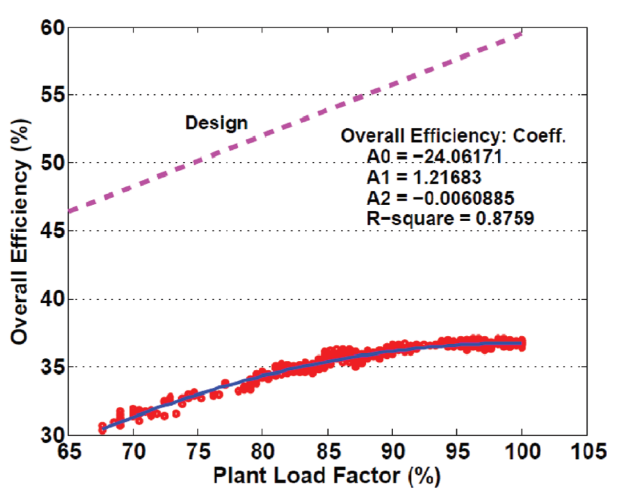

FIG. 7 VARIATION OF OVERALL EFFICIENCY OF PA FANS WITH PLF

4.3 Efficiency Variation

Similarly, the combined motor and fan (i.e., overall efficiency) is also plotted with PLF (Figure 7). The correlation coefficient of second order polynomial curve fit for the overall efficiency with PLF is 0.8759 and the noise level in data is high compared to flow. At MCR condition the average overall efficiency is 36.74 % and is lower than the design value of 59.52 % at MCR condition. The overall efficiency at full load capacity of PA fan (fan max. efficiency point) is 72.86 %. The power loss due to operating PA fans at design MCR condition is 0.09 % of gross generation and the power loss compared at actual measured operating point at MCR condition is 0.46 %. The overall efficiency is low because of higher PA fan discharge pressure, higher PA flow, problem in fan like over sizing of fan i.e., shift in operating point of fan design characteristics; change fan blade angle, clearance between impeller & casing, pitting & erosion of fan impeller, etc., [10]. The average overall efficiency at 70 % PLF is 31.28 % and is lower than the design value of 48.3 %. The deviation in overall efficiency at different plant loading is computed with respect to operating the plant load at MCR condition and the deviation (%) is computed as:

$$\partial\eta_O = \left(1 - \frac{\eta_T}{\eta_{MCR}}\right) \times 100 \quad \text{....(7)}$$

Where ηMCR is the overall efficiency at MCR condition (%)and ηT is the overall efficiency at tested plant load (%). The deviation in overall efficiency for operating the plant at 70 % of MCR is 14.9 %.

The motor efficiency (%) is computed based on the following correlation developed using MATLAB simulation:

$$\eta_M = 52.6212 + (\mathrm{LF} \times 2.2219) - (\mathrm{LF}^2 \times 0.0470312) + (\mathrm{LF}^3 \times 4.41689 \times 10^{-4}) - (\mathrm{LF}^4 \times 1.50641 \times 10^{-6}) \quad \text{....(8)}$$

Where LF is the load factor of motor (%) and is computed as:

$$LF = \frac{P_{in} \times \eta_M \times 100}{P_R} \quad \text{....(9)}$$

Where P_{in} is power input measured at motor terminals (kW) and P_R is motor rating (kW)

The load factor and motor efficiency are interrelated and are computed iteratively. The correlation coefficient of second order polynomial curve fit for the motor efficiency with PLF is 0.9596. The computed motor efficiency at MCR condition is 93.28 % and at 70 % PLF is 92.77 %. The power loss (kW) in motor is computed as:

$$L_M = P_{in}\left(1 - \frac{\eta_M}{100}\right) \quad \text{....(10)}$$

The correlation coefficient of second order polynomial curve fit for the power loss in motor with PLF is 0.8650. The computed power loss at MCR condition is 131.9 kW that forms about 6.72 % of total power input and at 70 % PLF is 127.4 kW.

The fan efficiency (%) is computed by:

$$\eta_F = \frac{\eta_O}{\eta_M} \times 100 \quad \text{....(11)}$$

The correlation coefficient of second order polynomial curve fit for the fan efficiency with PLF is 0.8699 and the noise level of data is high. The computed fan efficiency at MCR condition is 39.38 % and at 70 % PLF is 33.72 %. The power loss (kW) in fan is computed as:

$$L_F = (P_{in} - L_M) \times \left(1 - \frac{\eta_F}{100}\right) \quad ....(12)$$

The correlation coefficient of second order polynomial curve fit for the power loss in fan with PLF is 0.6226 and the noise level of data is very high. The computed power loss at MCR condition is 1108.9 kW that forms about 56.72 % of total power input and at 70 % PLF is 1084.2 kW.

4.4 Power Variation

The power input to PA fan motor is increased with increase in plant load (Figure 8). The correlation coefficient for the measured power input with PLF is 0.9474 and the noise level in data is less. At MCR condition the average measured power input is 1962 kW and is higherthan the design value of 1020.6 kW at MCR condition. The power input at full load capacity of PA fan (fan max. efficiency point) is 1205.4 kW. The actual measured power input is high because PA fans operating point is shifted thereby lower efficiency of fans, poor coal quality, higher PA flow and higher PA fan discharge pressure. The average power input at 70 % PLF is 1762.2 kW and is higher than the design value of 727.7 kW.

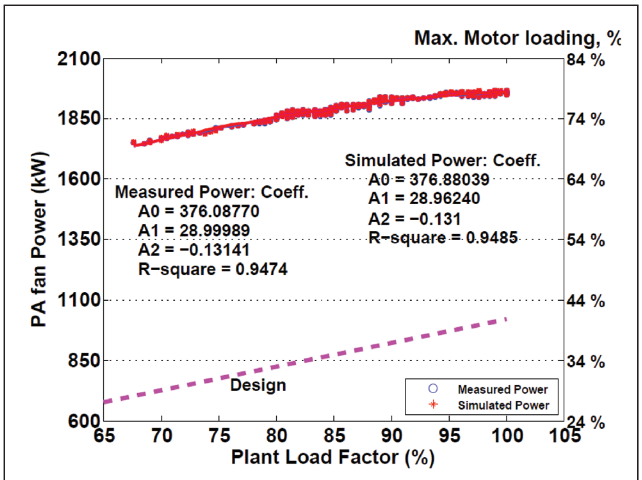

FIG. 8 MEASURED & SIMULATED POWER INPUT AT PA FANS WITH PLF

The power input to motor terminals is simulated using ANN technique and the correlation coefficient for the measured power input with PLF is 0.9474 and is slightly improved to 0.9485. At MCR condition the average simulated power input is 1962 kW and is slightly higher compared to measured value. The correlation coefficient between the measured input power and simulated power is plotted in Figure 9. The correlation coefficient computed (R^2) is 0.99978 and Root Means Square Error (RMSE) for the correlation is 0.00247.

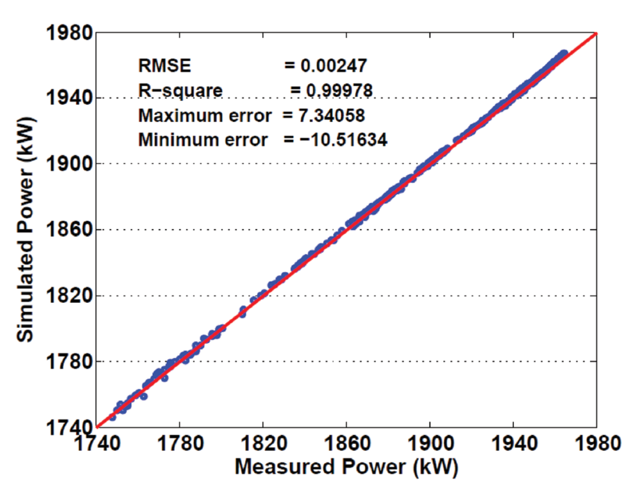

FIG. 9 CORRELATION COEFFICIENT BETWEEN MEASURED & SIMULATED POWER

The deviation in measured power input at different plant loading is computed with respect to operating the plant load at MCR condition and the deviation (%) is computed as:

$$\partial P_{PA} = \left(1 - \frac{P_T}{P_{MCR}}\right) \times 100 \quad ....(13)$$

Where P_{MCR} is the power input at MCR condition (kW) and P_T is the power input (kW) at tested plant load. The deviation in power input for operating the plant at 70 % PLF is 10.2 %.

In order to evaluate the auxiliary power used by PA fans, the specific auxiliary power (SAP) is computed which is the ratio of Power input to plant load (Figure 10). The specific auxiliary power (%) for PA fan motors is computed as:

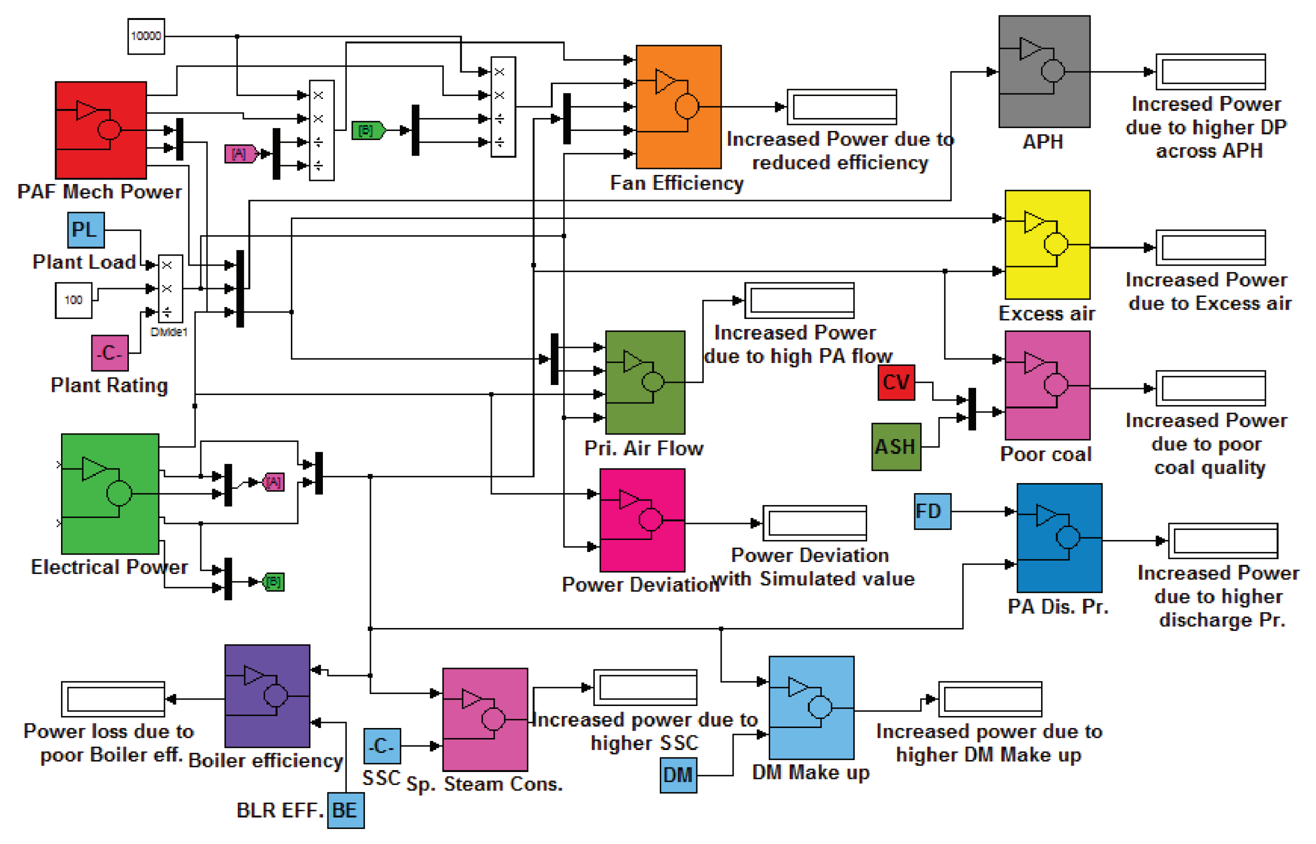

FIG. 10 MATLAB SIMULINK PROGRAM FOR PA FANS

$$AP_{PA} = \frac{P_{in}}{PL \times 10} \quad ....(14)$$

Where P_{in} is measured power input (kW) and PL is the plant load at generator output (MW).

The correlation coefficient for the measured SAP with PLF is 0.9954 and the noise level in data is less. At MCR condition the average SAP is 0.94 % and is higher than the design value of 0.49 % at MCR condition because of higher losses in fans.

The average SAP at 70 % PLF is 1.20 % and is higher than the design value of 0.50 %.

The correlation coefficient for the simulated SAP with PLF is 0.9954 same as that of measured value. At MCR condition the average SAP is 0.94 % and is same as that of measured value.

The deviation in measured SAP at different plant loading is computed with respect to operating the plant load at MCR condition and the deviation (%) is computed as:

$$\partial AP = \left(1 - \frac{AP_T}{AP_{MCR}}\right) \times 100 \quad ....(15)$$

Where AP_{MCR} is the SAP at MCR condition (%) and AP_T is the specific auxiliary power (%) at tested plant load. The deviation in specific auxiliary power for operating the plant at 70 % of MCR is increased by 27.7% and is high compared to pressure gain, flow & overall efficiency.

5.0 ENERGY CONSERVATION TECHNIQUES

The MATLAB Simulink programming is done to evaluate the performance of PA fans through implementation of energy conservation measures (Figure 10). This Simulink program input the simulated and curve fit coefficient values from the ANN program.

5.1 Excess Air

The optimum oxygen content at APH inlet will be 3.5 %. In many power plants, the operators, keep open higher FD fan blade pitch position to provide more air for combustion and also provide more primary air to lift the coal from mills to burners which leads higher excess air in furnace. In some other plants, the oxygen measuring port will not provide the average representative oxygen measurement may be due to improper placement of Zirconium oxygen probe in the furnace before APH. This misleads the operator to operate the plant with higher excess air. The higher excess air will increase the dry flue gas losses in boiler as well as increase the auxiliary power of PA fans. Figure 11 gives the increased auxiliary power of PA fans with oxygen content measured at APH inlet during performance test for the plant varying between 205 MW to 210 MW.

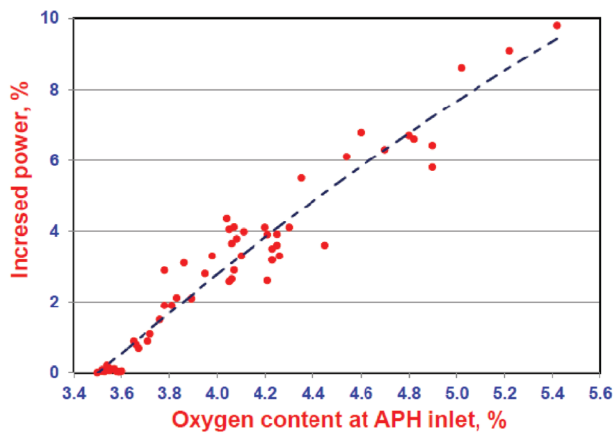

FIG. 11 INCREASED POWER PA FANS WITH HIGHER EXCESS AIR

TABLE 1

PERFORMANCE RESULTS OF PA FANS AT A TYPICAL 210 MW POWER PLANT.

Sl. No.	**Particulars**	**Unit**	**Simulated value at 97.86 % PLF**	**PAF 6A**	**PAF 6B**
01	Plant load (PLF)	MW (%)	-	205.5 (97.86)	
02	Motor rating	kW	**1250.00**	1250.00	
02	Suction pressure	kPa	-	-0.069	-0.069
03	Discharge Pressure	kPa	-	9.402	8.968
04	Pressure gain	kPa	**8.941**	9.471	9.037
05	Primary Air flow	m^3/s	**40.16**	48.53	47.98
06	Oxygen at APH inlet	%	**3.5**	4.12	4.30
07	Oxygen at APH outlet	%	**4.5**	7.32	7.31
08	Air leakage in APH	m^3/s	**3.33**	9.20	8.65
09	Pressure drop across APH	kPa	**1.02**	2.46	2.19
10	Electrical power input	kW	**978.30**	1257.59	1260.10
11	Load factor of motor	%	**72.95**	94.76	94.96
12	Loading pressure fan (fan rated capacity)	%	**75.32**	79.79	76.13
13	Loading flow fan (fan rated capacity)	%	**54.27**	65.58	64.84
14	Overall efficiency (design fan full load overall efficiency: 72.86 %)	**%**	**36.70**	36.55	34.41
15	Specific Energy Consumption	kWh/t	**6.51**	6.92	7.01
16	Specific Auxiliary Power	% of PL	**0.95**	**1.22**	
17	Power loss due to ΔP across APH	kW	**59.75**	119.4	105.1
18	Power loss due to air leakage through APH	kW	**55.9**	87.1	78.2
19	Increased power due to air leakage through APH	kW	-	31.20	22.30
20	Power saving by reducing the O_2 at APH inlet to 3.5 %	kW	-	16.85	20.60
21	Power saving by reducing fan discharge pressure 7.2 kPa	kW	-	292.4	246.5
22	Net Power saving	kW		340.45	289.4
23	New SAP	%	-	**0.92**	

The increased auxiliary power of PA fans (%) is curve fitted to second order polynomial and correlation coefficient (R^2 value) is 0.9394:

$$P_{EA} = -26.3404 + 9.19091 \times O_2 - 0.47795 \times O_2{}^2 \quad ...(16)$$

Where O_2 is the oxygen content in flue gas measured at APH inlet.

The performance tests are conducted at a typical 210 MW power plant. The performance results of PA fans are given in Table 1. The increased power loss in PA fans due to higher excess air is 37.45 kW (0.018 % of gross generation).

5.2 Air Leakage through APH

Generally in a 210 MW power plants, rotary regenerative type air preheaters are used to recover the heat from the outgoing flue gas [11]. The APH will be of tri-sectored where one sector is for flue gas (which will be at negative pressure), second sector is for secondary air whose pressure will be positive and third sector is for primary air whose pressure will be high. Both air flows will be in counter direction to flue gas flow in APH. In a typical 210 MW power plants APH, the opening for flue gas path is about 180° (50 % of total APH volume), for secondary air flow is about 130° (about 36 % of total APH volume) and for primary air flow is about 50° (about 14 % of total APH volume). At present to reduce the pressure drop across APH on PA side, the opening of PA duct is increased from 50° to 72° where the opening for PA flow will be about 20 % instead of 14 % and reduced for secondary air to 30 % instead of 36 % [12]. In order to reduce the air leakage through APH, presently double sealing (radial and axial seal) are being used.

Figure 12 gives the increased auxiliary power of PA fans with air leakage in APH during performance test for the plant varying between 205 MW to 210 MW. The increased auxiliary power of PA fans (%) is curve fitted to second order polynomial and correlation coefficient (R^2 value) is 0.9629:

$$P_{APH} = -2.3986 + 2.71928 \times \Delta O_2 - 0.272701 \times \Delta O_2{}^2 \quad ....(17)$$

Where ΔO_2 is the difference in oxygen content in flue gas measured at APH inlet and outlet.

It can seen from the Table 1 that the increased power loss in PA fans due to higher excess air is 53.5 kW (0.03 % of gross generation). The reduction of air leakage through APH by introducing the double sealing techniques (radial & axial seals) and also increasing the area for PA section from 50° to 72° will reduce the differential pressure across APH in PA section which is at higher pressure in the range of 9.0 to 9.4 kPa.

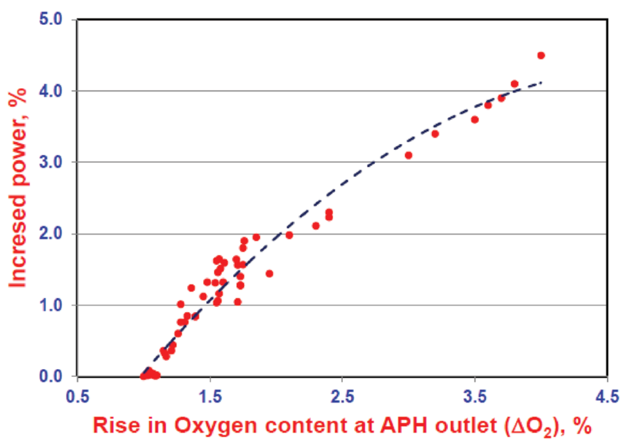

FIG. 12 INCREASED POWER PA FANS WITH AIR LEAKAGE IN APH

5.3 PA pressure drop across APH

In APH, the heat in the flue gas is transferred from flue gas to air through the baskets. The baskets are made up of steel metallic honeycomb like structure which are used to transfer the heat. Generally, soot blowers are installed just above the APH and near Economizer to clean the heating surface to enhance the heat transfer coefficient in Economizer. While operating the soot blowers, some part of the soot blowed steam converted to water particle which will mix with the fly ash present in flue gas that forms a cementing effect in air baskets in APH that will block APH. This will create a hydrodynamic resistance in flue gas and air circuits. These pressure drops increase the auxiliary power of Air fans. The pressure drop across APH on primary air side was measured in the range of 2.19 to 2.46 kPa which is higher than the design value of 1.02 kPa. Since the PA pressure is high, therefore the pressure drop across APH is also on higher side. The increased power of PA fans due to higher pressure drop across APH on PA side is 190.82 kW (0.09 % of gross generation) and the CO_2 emission is higher by 200 kg/h.

5.4 Higher discharge pressure of PA Fans

The design PA fan discharge pressure at MCR condition is 8.04 kPa whereas the design discharge pressure of PA fans at full capacity is 11.5 kPa. The pressure margin provided for PA fans is very high. The main purpose of PA fans is to deliver the primary air in such a way as to overcome the pressure drop across APH (i.e., about 0.42 kPa), mill differential pressure (i.e., about 3.64 kPa) and to carry the pulverized coal to burners at windbox. Figure13 gives the primary air pressure profile. The design PA pressure at mill inlet would be 6.43 kPa. The optimum value for PA fan discharge would be about 8.0 kPa. In many power plants, the PA fan discharge pressure is being maintained on higher side in the range of 8.8 to 9.4 kPa. The higher discharge pressure increases the auxiliary power of PA fans.

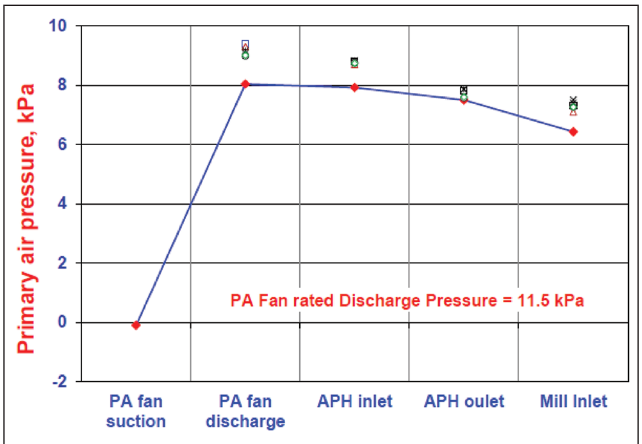

FIG. 13 PRIMARY AIR PRESSURE PROFILE

During the performance tests, the PA fan discharge pressure is measured and the pressure gain is presented in Table 1 for a typical power plant. The PA fan discharge pressure was measured in the range of 8.968 to 9.402 kPa. If the PA fan discharge pressure is reduced to about 8.0 kPa will reduce the auxiliary power of PA fans by 269.4 kW (0.13 % of gross generation) and the CO_2 emission is higher by 283 kg/h.

5.0 CONCLUSIONS

The power input to PA fans is simulated by using ANN technique using measured input parameters as pressure gain across fan, pressure drop across APH, overall efficiency and power input. The error between measured and simulated power input vary in the range of –10.52 to 7.34 % which is quite good. The SimulatedSAP is on par with measured value of 0.94 % at 100 % PLF and 1.22 % at 70 % PLF. The correlation coefficient (R2) value for measured SAP and for simulated SAP is same as 0.9954 which is good. The error is slightly high at lower plant load factor due to higher noise level in measured data. Optimizing excess air by monitoring the oxygen content at APH inlet will reduce the auxiliary power of PA fans by 37.45 kW (0.018 % of gross generation). Reducing the air leakage through APH will reduce the auxiliary power of PA fans by 53.5 kW (0.03 % of gross generation).Reducing the PA pressure drop across APH from 2.46 kPa to 1.02 kPa will reduce the auxiliary power of PA fans by 190.8 kW (0.09 % of gross generation). Optimizing the PA fan discharge pressure will reduce the auxiliary power of PA fans by 269.4 kW (0.13 % of gross generation). The implementation of energy conservation measures will reduce the overall auxiliary power of PA fans by 551.2 kW (0.26 % of gross energy generation) and also reduce the carbon emission by 4,056 t/year.

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